

Toward a physically-predictive theory of galaxy formation: resolved stellar and black hole feedback in a cosmological context

Over the past few years, cosmological hydrodynamic simulations have begun to produce galaxy populations with properties that agree broadly with observations. The successes of most existing simulations however rely on carefully tuning parameters of sub-grid models for core physical processes, such as star formation, stellar feedback, and supermassive black holes. I will describe a research program that aims to greatly improve the predictive power of galaxy formation simulations by directly resolving some of the key physical processes in the ISM of galaxies and developing approximations for unresolved processes that are directly calibrated using small-scale calculations. This approach, which we follow in the FIRE (Feedback In Realistic Environments) cosmological simulation project, largely eliminates the need for tunable parameters. I will present some early results on stellar feedback from this project, including on the physics shaping the galaxy stellar mass function, the origin of the Kennicutt-Schmidt law, the generation of galactic winds, the mass-metallicity relations, and observational diagnostics of circum-galactic gas flows. I will then outline our on-going efforts to model supermassive black hole growth and feedback in galaxy formation, and in particular discuss the physics of the recently discovered galaxy-scale outflows driven by active galactic nuclei.